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Generation of Syngas using Anacardium Occidentale

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ABSTRACT

The purpose of this project is to produce syngas from Anacardium occidentale shell which can be used in the piston engine of a short range helicopters like Mosquito XEL etc. which can be used for various applications like for agriculture fertilization and for local transport in an affordable price to the civilians. This anacardium occidentale is also known as cashew nut in most of the region. This project states the production of the syngas through downdraft gasification process as it is proven that it produces very less tar (waste) compared to other gasifiers. In this project, we will be also reusing the biomass char by converting it into an active catalyst which can be used for various applications like bio diesel production and in pyrolysis process to boost up the chemical reactions. This project also involves the waste management as we are running out of renewable resources of fuel such as fossil fuels which are obtained from the earth. In this project, we will be able to make use of such a fuel in the aviation industry which is obtained from a waste of a phytomass. In this project, we will be focusing on the production of this fuel from anacardium occidentale shells and study its characteristics by distinguishing with other phytomasses.

KEYWORDS: *Gasification, Syngas, Downdraft gasifier, Anacardium Occidentale, waste management, bio-fuel*

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I. INTRODUCTION

Usage of fossil fuel leads to harmful effects such as the global warming, acid rain and smog due to the emission production. In the future, bio energy can be one of the main sources of energy because of its renewability and net free carbon dioxide emission. About 32% of the total primary energy use in the country for heating and energy needs is the energy generated by biomass. Biomass gasification is a promising green root to convert solid biomass into gaseous fuel known as syngas which has multiple applications. The biggest challenge in front of the globe is achieving sustainable development. There are many technologies which help in achieving it and managing the growth of the society but there is an immediate requirement to resolve the problems faced today by the society without extending it and crating any negative impact for the future generations. Energy crisis is one of the most critical issues that affect our day to day lifestyle. Humans have advanced in various fields especially science and technology, but to run those technology we either need fuels or electricity. The fuels which are being used are the fossil fuels which are about to extinct. In order to save the fossil fuels we can use renewable energy as it doesn't affect our planet Earth with pollutants on a large scale. Biomass can be considered as a source of fuel. But the problem associated with biomass is the energy density. For example, an air-dried wood biomass contains an energy density of 112-15GJ/t, whereas sub-bituminous coal contains 20-25GJ/t. The extraction of energy from the biomass can be done through gasification. Crops as well as its residues from agriculture, forestry, and the agro-industry are the biomass available in many varieties. This biomass find their way as freely available fuel in rural and urban and also forest place. But these biomasses are also responsible for air pollution. Emissions of pollutants from such solid fuel combustion to indoor, regional and global air pollution largely depend on fuel types, combustion device, fuel properties, fuel moisture, and amount of air supply for combustion in technical terms. It also has an adverse effect on climatic conditions of that area or surrounding.

II. ANACARDIUM OCCIDENTALE

A. Anacardium occidentale

Cashew apple is pseudo fruit and is the part of the tree that connects it to the cashew nut, the tree's true fruit. The cashew apple is very popular and highly consumed as a drink and as concentrated juice. Cashew apple is rich in fructose, glucose, minerals, and several amino acids and is considered a good antioxidant with high ascorbic acid and phenols. Cashew (Anacardium occidentale L.), widely cultivated throughout the world, is a native of Brazil. It was one of the first fruit trees from the New World to be distributed throughout the tropics by the early Portuguese and Spanish adventurers, and it has a checkered history. In India, it was the British who contributed much to its popularity. A British butler also devised the vacuum packing using the soda making technique, enabling to prolong the shelf life of the nut. Kerala became the home of cashew nut and Kollam district its headquarters, where factories processing the nut sprang up, employing thousands of women laborers, even to this day. The nut became an important export commodity, earning the state much needed foreign currency. Considerable progress has been made during the last half century in developing high-yielding varieties.

B. Anacardium occidentale shells
The shell of the cashew seed yields derivatives that can be used in many applications including lubricants, waterproofing, paints, and arms production, starting in World War II. Due to the possible dermatitis, cashews are typically not sold in the shell to consumers. Readily and inexpensively extracted from the waste shells, cardanol is under research for its potential applications in nanomaterials and biotechnology.

III. DOWNDRAFT GASIFICATION
A. Downdraft gasifier
A downdraft gasifier is a gasification reactor with four distinct zones: (a) upper drying zone, (b) upper-middle pyrolysis section, (c) lower-middle oxidation zone, and (d) lower reduction zone. A downdraft gasifier is favored due to its easy fabrication and due to low tar content in the synthesis gas. This work presents a designed and experimental result of downdraft gasifier. The throat, the smallest cross-sectional area, is approximately 175 millimeters. The gasifier is divided into 2 pieces (top and bottom) for easy fabrication and cleaning of the internal parts. The top is a fuel chamber while the bottom is a reaction and ash chamber. This gasifier was made of carbon steel inserting multi-tube carbon steel of 1 inch diameter to be outlets of synthesis gas. Experimental results showed that average volumetric percentage in the synthesis gas were 39.71 % CO, 16.48 % CO_2, 36.26 % H_2 and 7.55 % CH_4. The gasification efficiency of this work of 40.47 % can be achieved. Brar et al. commercialized the preparation of down- draft gasifier which was gasified using the combination of bituminous coal and pellets of hardwood which were mixed inside the gasifier as gasifying agents in different proportions and signified the increase in efficiency of the carbon which was increased with the increase in the proportion of the input coal but it eventually lead to decrease in the contents of hydrogen and carbon monoxide which were present in the producer gas that was obtained from the down-draft gasifier (1).

Figure 1: DOWNDRAFT GASIFIER

Phuet Prasertcharoensuk et al investigated in a 20 cm diameter throat downdraft gasifier and optimised using computational fluid dynamics modelling. The properties of gas and temperature profile in a gasifier system was systematically investigated and validated using experimental data with effect of throat diameter and also position of air nozzles. Alka D. Kamble et al investigated that in order to achieve high thermodynamic efficiency and relatively low CO_2 emission co-gasification of coal and biomass is efficient technology. Chemical composition of biomass helps to ignite and enhances the gasification process (2). The study revealed that, the small-scale cashew processing industries followed steam-cooking process with average energy consumption accounted to be 2969.7 MJ per 1000 kg of raw cashew seed. The cashew shell waste generated in small-scale cashew processing industries was found to be 67.5% of total weight of cashew seed, which can be utilized as fuel for thermal energy supply. The average higher calorific value of the cashew nut shell was found to be 4890 kcal/kg. The thermo gravimetric analysis revealed that 85% weight of cashew nut shell has been degraded at 500°C and in 13 minutes. The availability and fuel analysis of the cashew shell as a fuel revealed its suitability as a supplementary fuel for thermal application through pyrolysis in the industry (3).

B. Biomass selection.
The biomass selection is the process of selecting the required biomass that we are going to use in the syngas production. The biomass used here is anacardium occidentale which is also known as cashew nut shells. These cashew nut shells are waste products obtained after the cashew nuts are taken from the cashew nut fruit. They are widely found in all over India and other parts of the world. They are widely used in many industries for the production of products like paints, laminating resins, and in various chemical industries. Here the cashew nut shells are collected from a small scale bakery industry that uses cashew nut for their cake production. These industries throw away the shells as the waste products. These shells can be used for many purposes like production of fuel and it is much more advantageous as they are available on a large scale.

C. Pretreatment
The pretreatment process is the preprocess done on the feedstock before getting its characteristics and feeding it to gasifier for gasification. The processes involved are •Drying •Crushing •Sizing

1. Drying
Initially the feedstock is dried at an atmospheric temperature in the presence of sunlight for 2- 3 days. This is done to remove the moisture content present in the shells.

2. Crushing
The dried feedstock is then crushed with the help of mortar and pestle or with the help of a mixer by grinding it into very small pieces. This fine grinded feedstock is then further processed.

3. Sizing
The grinded feed stocks are then sized with the help of sleeve of various sizes. The sized feed stocks are then separated and the remaining feedstock is again grinded.

D. PROCESS
The feedstock in the gasifier is burnt in the gasifier through down draft gasification leading to formation of syngas i.e. H2 + CO. The left over ash and char are reused to form bio-catalyst that is used to speed up the reaction process and even can be used as activated carbon. The syngas produced is filtered and compressed with the help of compressor and injected back to the 2- stroke helicopter engine with the help of injector.

IV. EXPERIMENTAL SETUP FOR ANALYSIS
The experimental set up of this involves the following components which are Gasifier (Downdraft Gasifier), Shells of Anacardium Occidentale, HCL acid, Coal pellets, Beaker or jar for collecting the gas, Mortar and Pestle, Mixer to grind the feedstock, Gloves and Safety utilities.

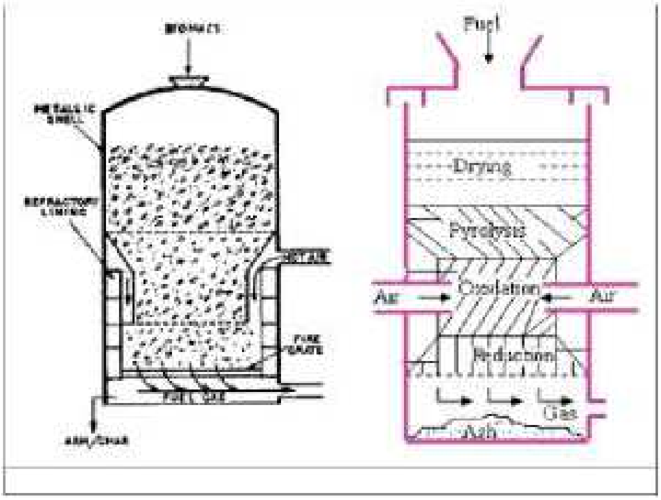


Figure 2: DIAGRMATIC REPRESENTATION OF DOWNDRAFT GASIFIER

A. BASIC SYSTEM WORKING

Initially, a small amount of charcoal was loaded and a fire was then lit by burning oil soaked papers on top of the charcoal to spread the fire across the surface. The blower was started, drawing air in through the open top of the reactor to sustain combustion. Immediately afterwards, biomass fuel was loaded fully and the top cover was closed. Air was supplied and regulated by means of valves such that oxidation zone inside the gasifier can be established and gaseous products produced from the biomass was combustible. At the beginning, white opaque smoke was released. It could not be ignited. After about 10–15 min, the producer gas obtained became less opaque and more combustible. A flame at the gas burner could be established. Producer gas was utilized to provide hot water in the factory. Limited test runs were performed for water boiling test to evaluate the thermal performance of the system. Measurements were taken by monitoring fuel consumption rate and amount of water used on an hourly basis. Gas temperature at the gasifier exit and flame temperature were measured every 10 min. This gas exiting the gasifier are collected and preserved in a gas bag and sent for analysis.

V. CHARACTERIZATION

The process of characterization involves the following processes like Proximate analysis, Ultimate analysis, TGA, XRD, CALORIFIC VALUE and GAS CHROMATOGRAPHY

A. Proximate analysis

Proximate analysis of a fuel provides the percentage of the material that burns in a gaseous state (volatile matter), in the solid state (fixed carbon), and the percentage of inorganic waste material (ash), and is therefore of fundamental importance for biomass energy use (3).

B. Ultimate analysis

Ultimate analysis is basically a breakdown of the fuel into its elemental components through an analysis of the products that remain after the complete combustion of a small fuel sample. Ultimate analysis gives the elemental composition of a fuel. Its determination is relatively difficult and expensive compared to proximate analysis (4).

C. TGA

Thermo gravimetric analysis (TGA) is an analytical technique used to determine a material's thermal stability and its fraction of volatile components by monitoring the weight change that occurs as a sample is heated at a constant rate.

D. XRD

X-Ray Diffraction, frequently abbreviated as XRD, is a non-destructive test method used to analyze the structure of crystalline materials. XRD analysis, by way of the study of the crystal structure, is used to identify the crystalline phases present in a material and thereby reveal chemical composition information.

E. Calorific value

A bomb calorimeter is a type of constant-volume calorimeter used in measuring the heat of combustion of a particular reaction. Bomb calorimeters have to withstand the large pressure within the calorimeter as the reaction is being measured. An apparatus primarily used for measuring heats of combustion. The reaction takes place in a closed space known as the calorimeter proper, in controlled thermal contact with its surroundings, the jacket, at constant temperature. This set, together with devices for temperature measurement, heating, cooling, and stirring comprise the calorimeter.

F. Gas chromatography

Gas chromatography is used to separate and measure various types of gases . It is a sensitive technique, can analyze small samples, and can be automated, but is also relatively expensive and requires technical knowledge (5).

VI. RESULTS AND DISCUSSIONS

In this paper, we are mainly focusing on the analysis of the syngas or producer gas generated from the shells of anacardium occidentale with the help of downdraft gasifier. The main analysis involved here are proximate, ultimate, TGA, XRD analysis and calorific value.

A. ELEMENTAL ANALYSIS

The elemental analysis involves the following analysis which includes ultimate analysis and proximate analysis.

1. RESULTS FROM PROXIMATE ANALYSIS

From the table 1, it is clearly stated that the moisture content present in the biomass sample is 9.43% along with volatile matter, ash and fixed carbon with 72.93%, 3.62% and 19.16% respectively

Biomass Sample	Moisture%	Volatile Matter%	Ash%	Fixed Carbon%
Cashewnut shell	9.43	72.93	3.62	19.16

Table 1: Results from proximate analysis

2. RESULTS FROM ULTIMATE ANALYSIS

From the table 2, it is clearly stated that the given biomass consist of 51.19% of carbon along with 13.96% of Sulphur, 7.007% of hydrogen and 0.644% of nitrogen. This testing of biomass is done in a dry state of biomass.

Biomass	C %	S%	H%	N%
Cashewnut shell	51.19	13.96	7.007	0.644

Table 2: Results from ultimate analysis

B. EMPIRICAL FORMULA AND CALORIFIC VALUE

From the result from table 3, it is clear that the empirical formula of the anacardium occidentale or cashew nut shell is $CH_{1.63}O_{0.40}N_{0.0107}S_{0.1023}$. An empirical formula is proposed which allows one to calculate the lattice constant of cubic synthetic oxides–garnets taking into account the chemical composition, the distribution of cation in the crystallographically non equivalent positions.

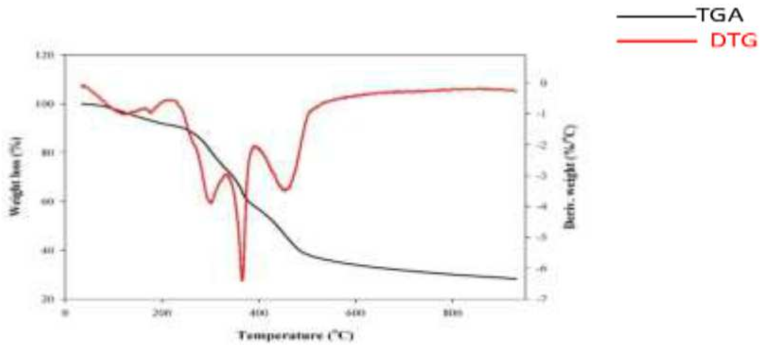
The calorific value obtained is 20.47Mj/kg from the bomb calorimeter, whereas experimental values given are 20.42 Mj/kg and literature values are 20.44 Mj/kg.

Sl. No.	Biomass Sample	Empirical formula				Calorific value (predicted) (Mj/kg)	(Experiment) (Mj/kg)	Literature (Mj/kg)
1	Cashewnut shell	CH	0	N	S	**20.47**	**20.42**	**20.44**
		1.63	0.40	0.0107	0.1023			

Table 3: Results from calorific value and empirical formula analysis

C. RESULTS FROM TGA ANALYSIS

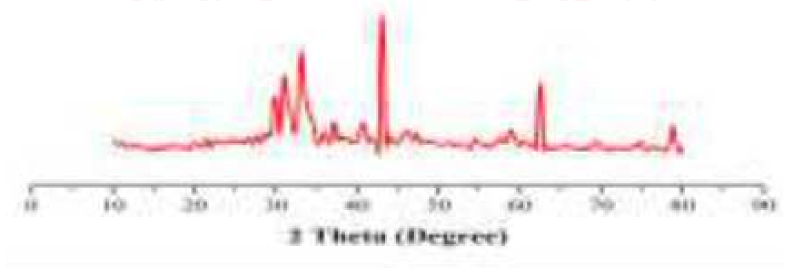
The TGA and DTG curve also known as Thermogravimetric analysis and Derivative Thermogravimetry analysis is done for the given syngas derived from biomass called anacardium occidentale. It is shown that the temperature is directly proportional to the weightloss % in TGA analysis. Initially upto 300 °C there is only a small weight loss % but with increase in temperature above 300 °C, there is drastic fall in the weight loss % of biomass. Derivative weight is the ratio of weight loss % per °C. There is a small fluctuation in the DTG analysed graph which can be seen in the graph 1.



Graph 1: TGA and DTG curve for CNS shell

D. RESULTS FROM XRD ANALYSIS

The XRD pattern of the Cashew nut shells shows the pattern as in graph 2 exhibited on the angle 2 theta (degree). The pattern clearly shows at an angle 40° and 50° there is maximum elevation. Similar elevation is found in angles like 63° and between 25° and 35°. There are no variations at angle of 0° and 90°.



Graph 2: XRD pattern for CNS shell

E. GASIFICATION REACTION ZONE

The reaction zone observed in the gasification process are :-

Drying zone: $H_2O(l) \Rightarrow H_2O(g)$ (1)

Pyrolysis Zone: Biomass => $Char_{(s)}$ + Volatiles + $CH_4 + CO + H_2 + N_2$ (2)

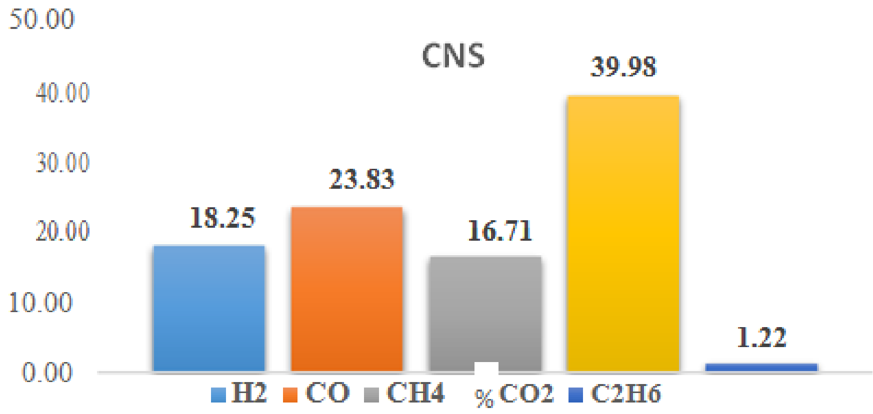
Oxidation Zone: Combustion: (Char/Volatiles) $C + O_2 \Rightarrow CO_2$ (3)

Partial Oxidation: (Char/Volatiles) $2C + O_2 \Rightarrow 2CO$ (4)
$2CO + O_2 \Rightarrow 2CO_2$ (5)

Reduction Zone: CO Methanation: $CO + 3H_2 \Rightarrow CH_4 + H_2O$ (6)
$2CO + 2H_2 \Rightarrow CH_4 + CO_2$ (7)
Water-gas shift: $CO + H_2O \Leftrightarrow CO_2 + H_2$ (8)
$CH_4 + H_2O \Rightarrow CO + 3H_2$ (9)

F. RESULTS FROM GAS CHROMOTOGRAPHY

The gas chromatography clearly states the gas compositions present in the syngas. The gas composition includes the following components represented in the graph 3.



Graph 3: Results from gas chromatography

It is seen that the hydrogen content present in the syngas produced from Cashewnut shell or anacardium occidentale is nearly 18.25 % where as carbon monoxide present is 23.83% which is the second highest among the group. The highest percentage is carbon dioxide which consist of 39.98 % and methane gas is in the range of 16.71 %. These gas compositions were discovered using the gas chromatography.

G. LHV OF SYNGAS

The low heating value of the syngas produced from anacardium occidentale shells was found to be 11.78 Mj/kg.

Sl. No.	Biomass Sample	LHV(syngas) (Mj/kg)
5	Cashewnut shell	**11.78**

Table 4: LHV of syngas

H. EXERGY OF SYNGAS

The cashew nut shell or anacardium occidentale shell biomass has an exergy value of 20.34 Mj/kg along with LHV value of 16.41 Mj/kg and co-relation factor of 1.24. The empirical formula for the anacardium occidentale is $CH_{1.63}O_{0.40}N_{0.0107}S_{0.1023}$.

Sl. No.	Biomass Sample	Empirical formula	(LHV of biomas) M J/kg	B (Correlation factor)	Exergy of Biomass (Mj/kg)
1	Cashewnut	$CH_{1.63}O_{0.40}N_{0.0107}S_{0.1023}$	**16.41**	**1.24**	**20.34**

Table 5: Exergy of syngas

VII. CONCLUSION

On the basis of obtained result, it can be concluded that Anacardium occidentale is vastly found in many places of India and all other parts of the world. Shells of anacardium occidentale are rarely used for any purpose and are a waste product which can be utilized by recycling it as an active biofuel. When compared with many other biomasses, anacardium occidentale has proven with high exergy value which has made it to have high calorific value. When tested in a bomb calorimeter, it was resulted that the calorific value of anacardium occidentale. The gas composition of the syngas produced were determined from gas chromatography which showed that the syngas produced from anacardium occidentale have the low heating value of the syngas produced from anacardium occidentale shells was found to be 11.78 Mj/kg. The cashew nut shell or anacardium occidentale shell biomass has an exergy value of 20.34 Mj/kg along with LHV value of 16.41 Mj/kg and co-relation factor of 1.24. The empirical formula for the anacardium occidentale is $CH_{1.63}O_{0.40}N_{0.0107}S_{0.1023}$. The hydrogen content present in the syngas produced from Cashewnut shell or anacardium occidentale is nearly 18.25 %. Carbon monoxide present is 23.83 which is the second highest among the group. The highest percentage is carbon dioxide which consists of 39.98 % and methane gas is in the range of 16.71 %. The above XRD pattern of the Cashewnut shells shows the pattern exhibited on the angle 2 theta (degree). The pattern clearly shows at an angle 40^{o} and 50^{o} there is maximum elevation. Similar elevation is found in angles like 63^{o} and between 25^{o} and 35^{o}. There are no variations at angle of 0^{o} and 90^{o}. From the proximate analysis result, it is clearly stated that the moisture content present in the biomass sample is 9.43% along with volatile matter, ash and fixed carbon with 72.93%, 3.62% and 19.16% respectively. From the above analysis result, it is clearly stated that the given biomass consist of 51.19% of carbon along with 13.96% of Sulphur, 7.007% of hydrogen and 0.644% of nitrogen. This testing of biomass is done in a dry state of biomass. Hence, from the above results several studies were done to conclude that anacardium occidentale is also capable of being used as an alternative biofuel replacing the fossil fuels. These syngas from anacardium occidentale can be made use in 2 stroke gasoline piston engine which is made use in a helicopter like mosquito XEL.These helicopters can be made use in local purposes like transportation, agriculture etc.

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